

Analysis of “Dirt” Events in MicroBooNE

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Introduction

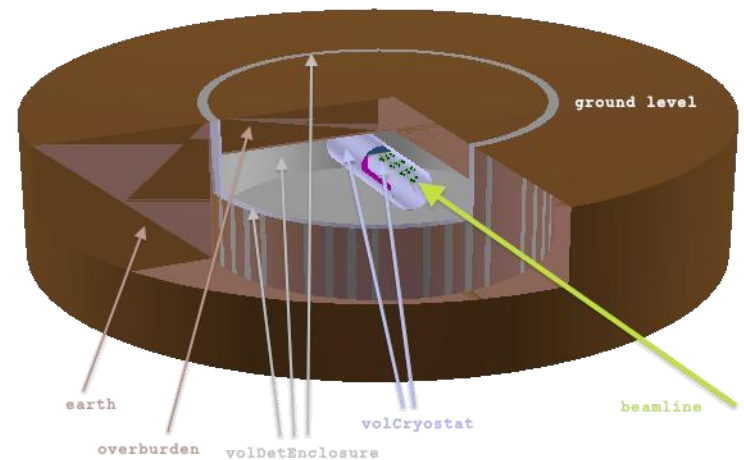
- This study was done to analyze events that occur outside the active volume of the MicroBooNE TPC and produce background inside, called “dirt” events
- The information in this study can be used to predict how many misleading background events should be expected in real-life MicroBooNE runs

Event Generation

- Events were generated using GENIE then propagated through the geometry with Geant4
- They were generated with all standard MicroBooNE settings except the beam radius (set to 50.0 meters)
- The flux files used were generated for a 6.106m beam radius at the MiniBooNE location and the beam radius was set to 50.0m for the simulation
 - A more accurate flux file was not available at the time of this study (implications of using the 6.106m file will be discussed at the end)

Geometry

- The setup volWorld from the LArSoft Geometry class was used
 - Contains the TPC, centered at (128 cm, 0 cm, 600 cm) with dimensions 2.56 m (horizontal) x 2.4 m (vertical) x 12.0 m (longitudinal)
 - In this study, the fiducial volume is defined as a box with sides 17.5 cm in from all sides of the TPC
 - Cryostat with 1.93m outer radius
 - The Cryostat is inside an Enclosure surrounded by earth



volWorld

Simulation Overview

- Events that occur outside the fiducial volume (in the cryostat, enclosure, or earth) and their daughter particles are considered
- Neutrinos, nuclei, electrons, particles with energy below 10 MeV and particles that originate very far away (in secondary neutrino interactions) are ignored
- Starting and ending positions, kinetic and total energies and species of particles are considered

Simulation Overview (continued)

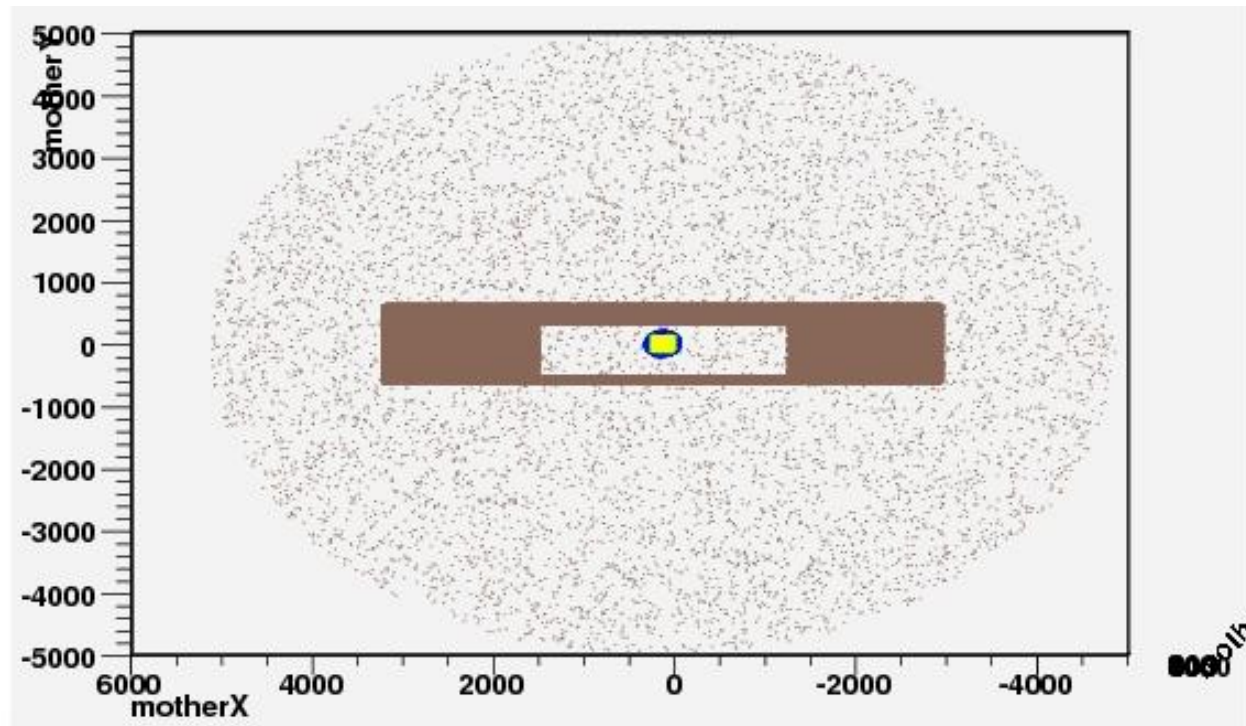
- Particles that “terminate” (decay, collide or react) inside the detector, those that go through and those that start inside but terminate outside are considered separately
- Daughter particles that make it inside the active volume but not the fiducial volume are also considered
- Particles from events inside and outside the cryostat are considered separately
- Photons, neutral pi mesons (π^0) and neutral delta baryons (Δ^0) and their daughters are also considered separately

Simulation Overview (continued)

- Delta particles are found by matching their daughter particles (energy and PDG code) from GENIE with “primary” particles (those involved in the initial reaction) in Geant4
- Sometimes their daughter particles are produced in the nucleus and later ejected. The ejected particles are listed as the “granddaughters” of the Δ^0 and they are considered as well
- Only Δ^0 are considered this way, not Δ^\pm

Event Vertices

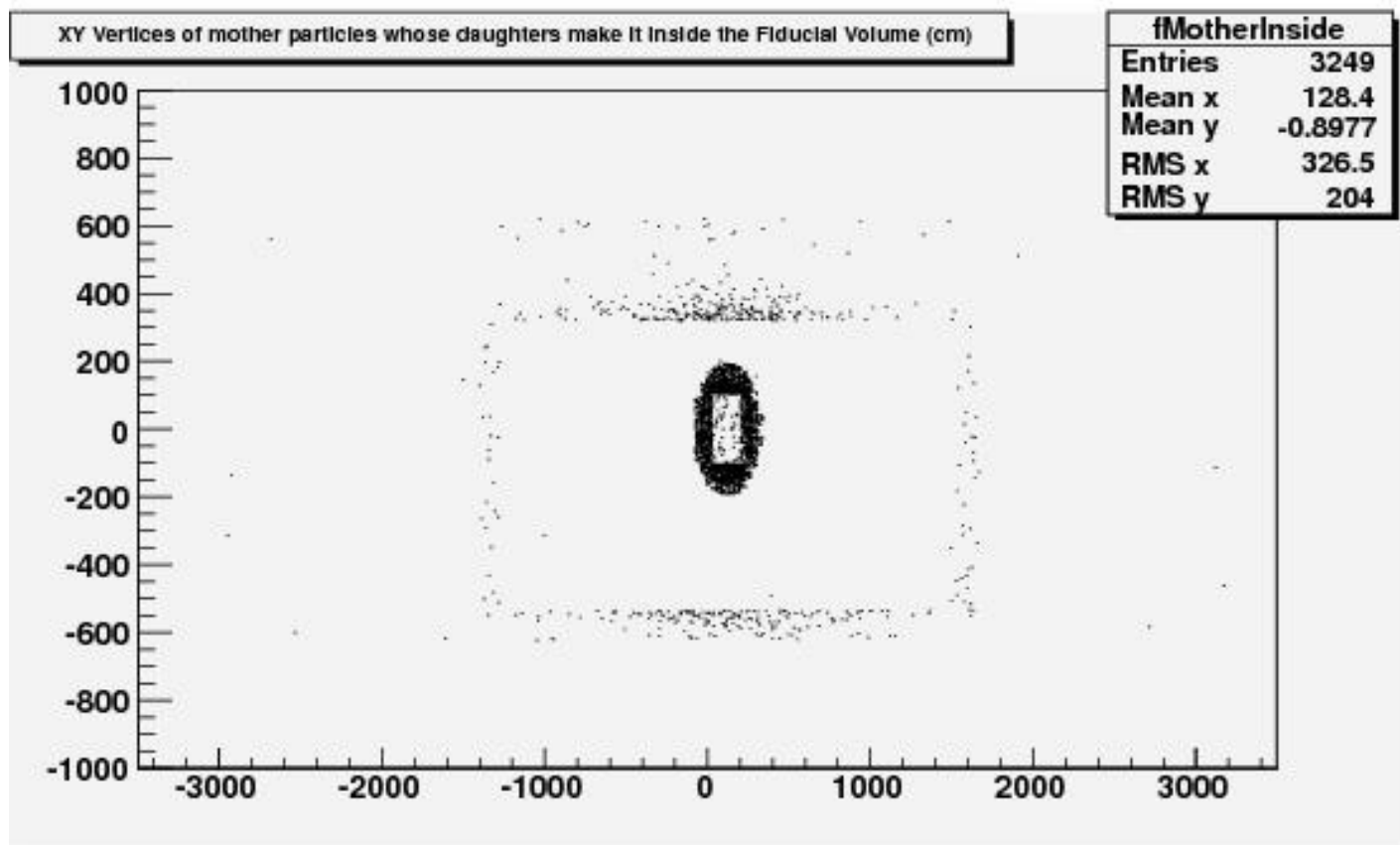
- Vertices of neutrino reactions are shown in the picture below
 - Inside the fiducial volume (yellow), in the active volume but outside the fiducial volume (green), inside the cryostat (blue), outside the cryostat (brown)



Qualitative/General Results

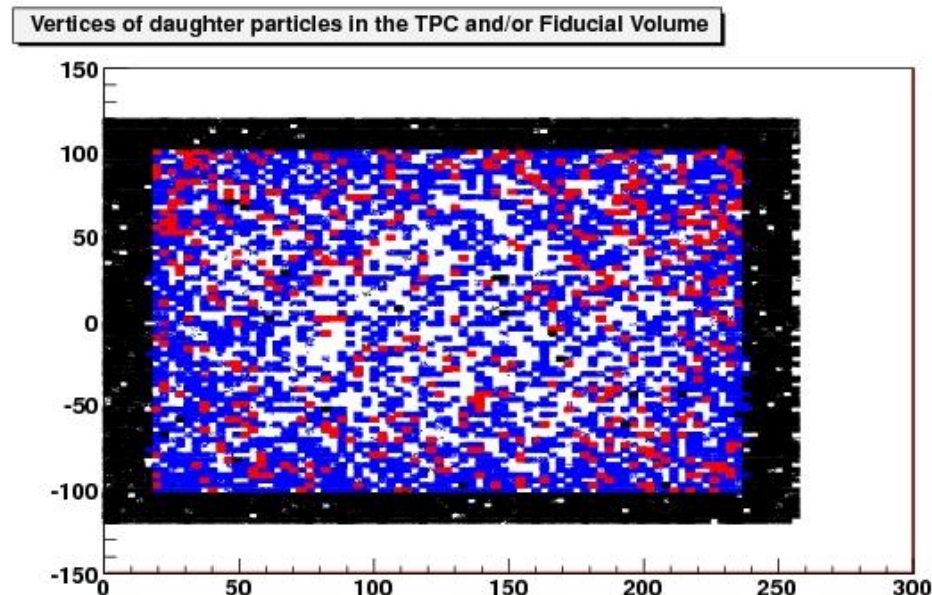
- It was found that most of the events producing daughter particles inside the detector occur inside the cryostat.
- 8,044 daughter particles from cryostat events make it inside the fiducial volume at some point (terminate in, start in and go out or go through)
 - A few of these occur in front of or behind the fiducial volume along the beamline
- Only 1,082 come from external (outside cryostat) events

Vertices of Relevant Events



Where Daughter Particles Decay

- Most of these daughter particles decay close to the edges of the fiducial volume



Decay vertices of daughter particles inside the TPC but outside the fiducial volume (black) and inside the fiducial volume from events inside the cryostat (blue) and outside the cryostat (red)

Types of Daughter Particles

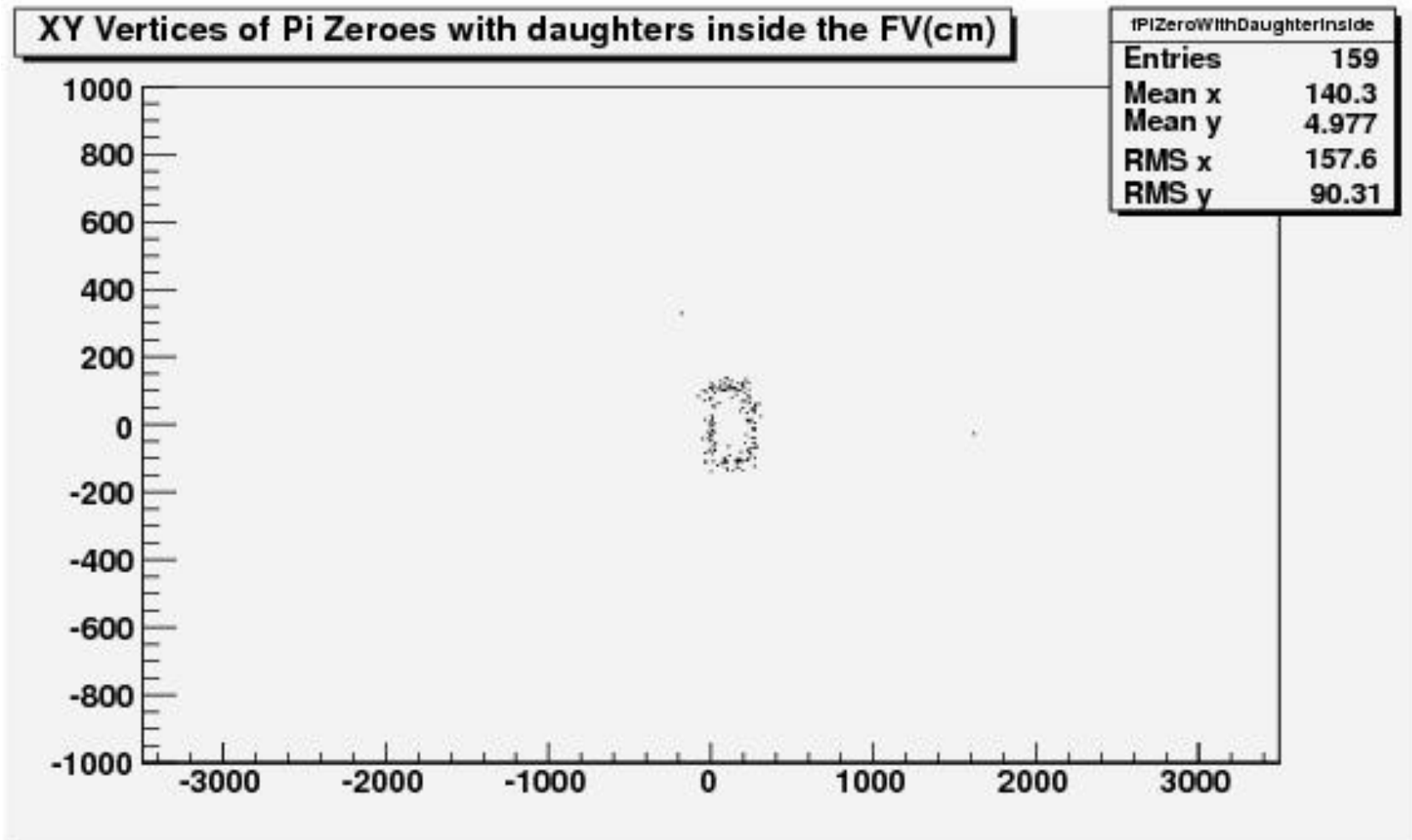
- The particles that make it inside the fiducial volume are mainly nucleons. The next biggest contributions are from leptons, then photons, then pi mesons.
- Most of the particles that go through the fiducial volume are leptons
- For the most part, these don't matter

Single Photons from π^0 Decays

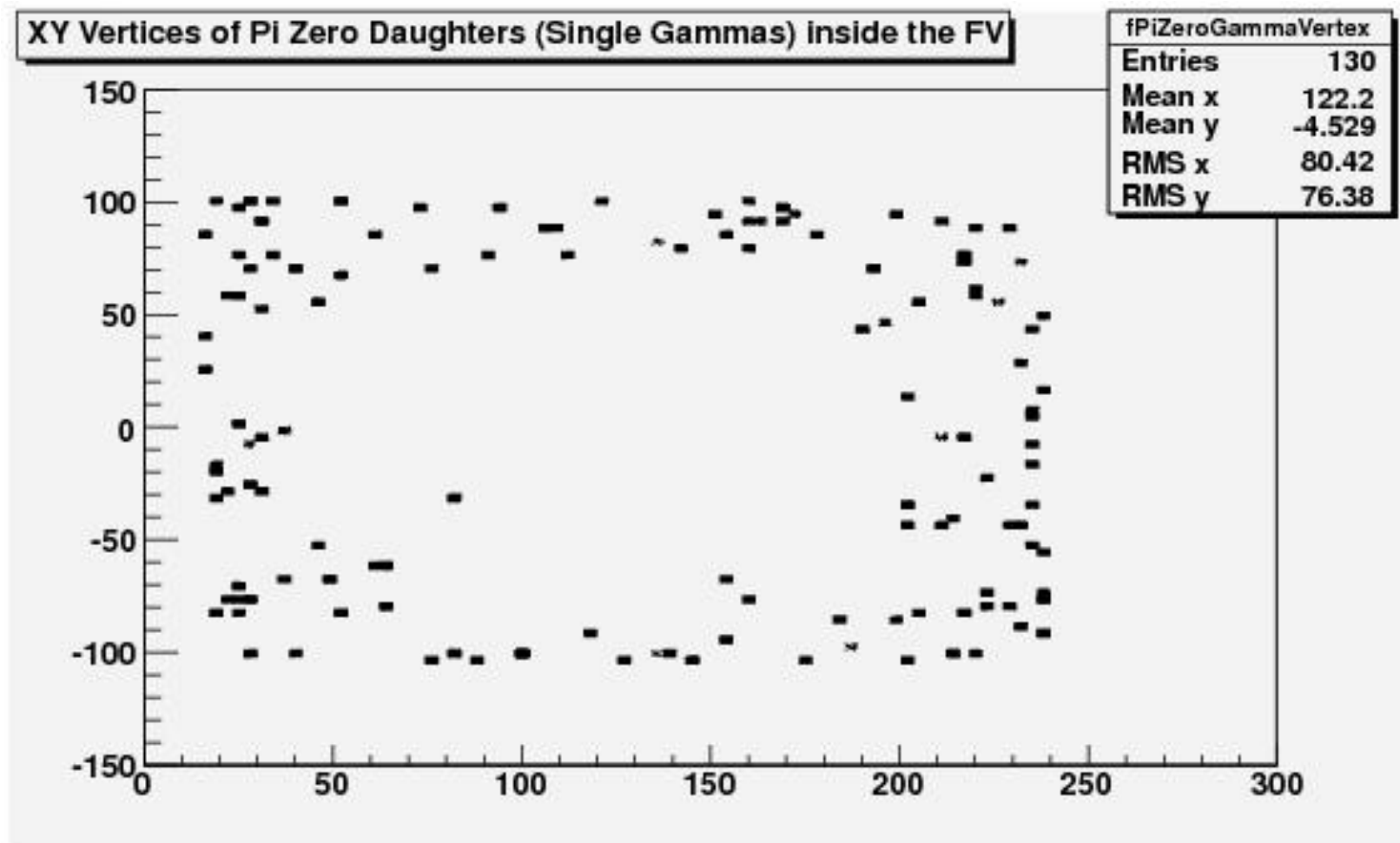
- Most misidentified “dirt” interactions come from π^0 decays outside the detector
- All but 3 were from events inside the cryostat

	Number of π^0
π^0 producing any daughters inside the fiducial volume	159
π^0 producing a single photon inside the fiducial volume	130
π^0 producing a single photon inside the fiducial volume without any other charged particles present	97

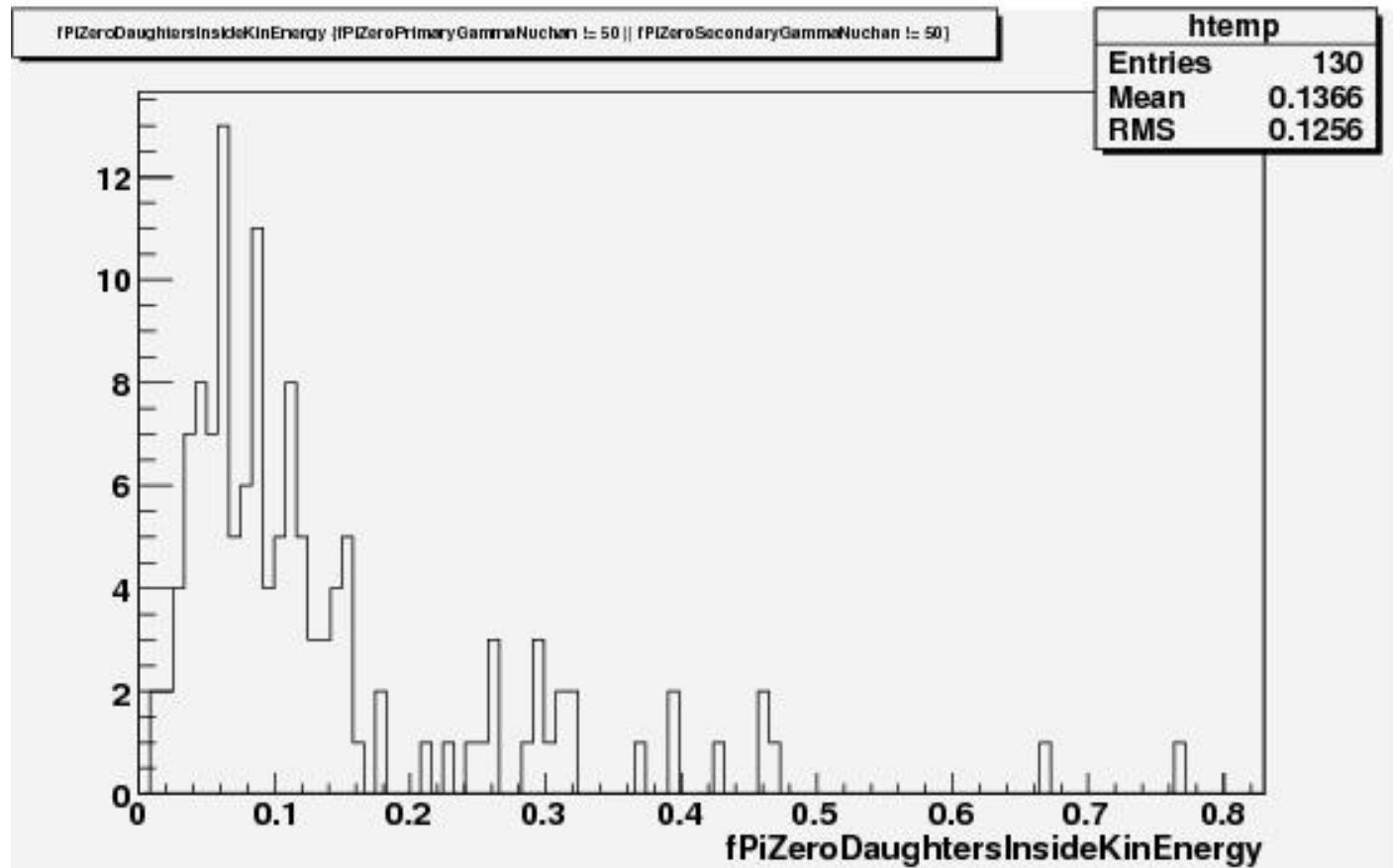
Vertices of π^0 Decays that Produce Background



Where the Photons Pair Produce



Energy of Single Photons (GeV)



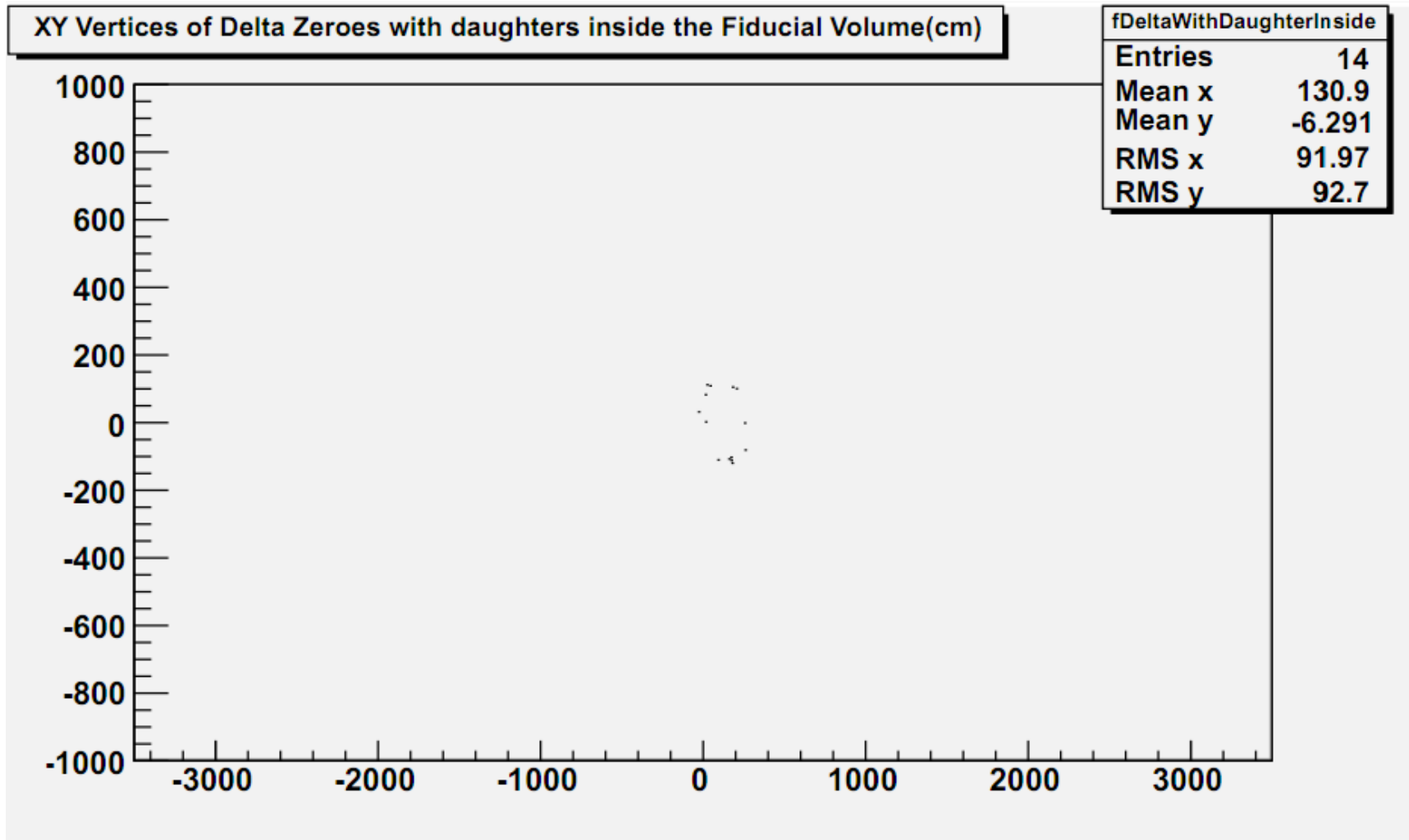
Where the π^0 Come From in Neutrino Mode

Reaction Type	Number of π^0 producing single photons in the detector	Percentage of Total
Resonant single pion production	70	53.85%
Multi-pion resonant processes	11	8.46%
Deep inelastic scattering	34	26.15%
Coherent/diffractive	1	0.77%
Subtotal (all primary reactions)	129	89.23%
Inelastic collisions (π^+ , π^- , p^+)	12	9.23%
Decay (Λ^0)	2	1.54%
Subtotal (all secondary interactions)	14	10.77%
Total	130	100.00%

Photon Production from Δ^0 Decays

- In this simulation, 14 Δ^0 produce daughter particles inside the detector, although none of them are photons (all π^- and p^+)
- These decays are closer to the detector than those of the π^0 that produce background
 - None come from outside the cryostat

Positions of Relevant Δ^0 Decays



Anti-Neutrino Mode

- Most plots from anti-neutrino mode looked very similar to those from neutrino mode

	Number of π^0
π^0 producing a single photon inside the fiducial volume	143
π^0 producing a single photon inside the fiducial volume without any other charged particles present	111

- 11 Δ^0 produce daughter particles inside the fiducial volume

Where the π^0 Come From in Anti-Neutrino Mode

Reaction Type	Number of π^0 producing single photons in the detector	Percentage of Total
Resonant single pion production	60	41.96%
Multi-pion resonant processes	28	19.56%
Deep inelastic scattering	37	25.87%
Coherent/diffractive	4	2.80%
Subtotal (all primary reactions)	129	90.21%
Inelastic collisions (π^+ , π^- , p^+)	13	9.09%
Decay (Λ^0)	1	0.70%
Subtotal (all secondary interactions)	14	9.79%
Total	143	100.00%

Scaling

- The events are scaled by comparing the events/POT for the simulation to events/POT values calculated using expected event rates for the volumes in both cases (73.9 tons in the simulation/64.1 tons for expected event rates)
- We obtained scaling factors of 0.211 and 0.120 for neutrino and anti-neutrino mode, respectively*

*See backup slides for math

Scaled Predictions for MicroBooNE Runs

	Number of Events in Neutrino Mode	Number of Events in Anti-Neutrino Mode
$\pi^0 \rightarrow \gamma\gamma$	1.23	0.798
$\Delta^0 \rightarrow N\gamma$	0.00108*	0.00048*
Total	1.23	0.798

- Values shown in the above table have been multiplied by 0.06 to reflect the assumption that there will be 94% efficiency in differentiating between photons and electrons in MicroBooNE.
- The number of misleading events due to $\Delta^0 \rightarrow N\gamma$ was calculated using the branching ratio for this process (since none were actually seen in the simulation)
- *Based on these figures, it is probable that there will be no “dirt” contribution from the process $\Delta^0 \rightarrow N\gamma$

Caveats

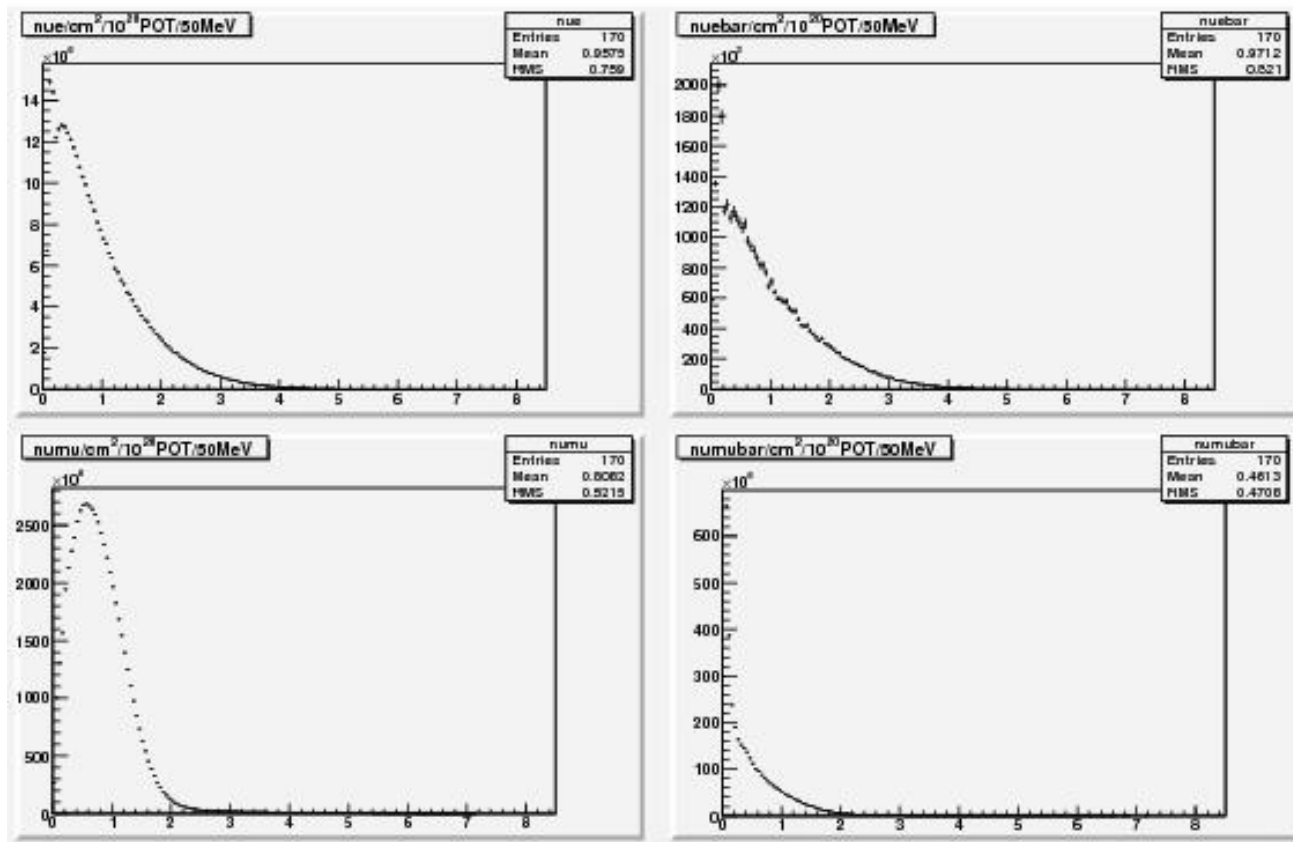
- We used a flux file with a 6.106m beam radius and used that file to generate events in a 50.0m beam radius
 - Between a 2m beam radius and a 14m beam radius file, there was less than a 15% difference in the number of events
 - Based on this, it can likely be said that there will not be too much distortion of events using the 6.106m beam radius flux file
 - We still need to check using newer flux files whether these effects are indeed small
- The dimensions of the TPC are not perfect either since they have been changed as revisions to the TDR are made

Conclusions

- Study was performed in both anti-neutrino and neutrino mode
- Only single photons were considered for the dirt background
- 1 (or fewer) event will create background in either mode, close to the numbers predicted in the MicroBooNE Proposal
- This study has some caveats but they should not impact the results by a lot: Flux file could introduce a difference of 10-15% but this can be scaled, as can the effect of the modified geometry
- We may be able to say more about this once reconstruction is done

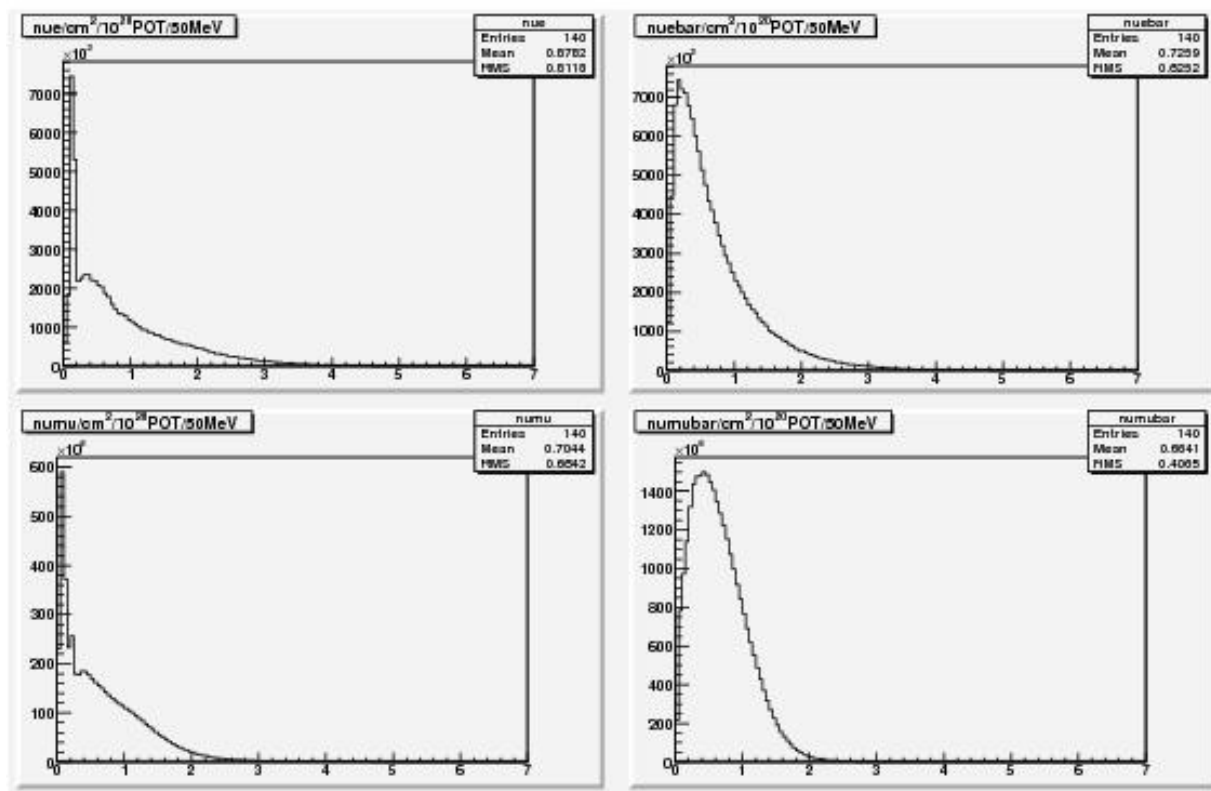
BACK UP SLIDES

Flavor Histograms for Neutrino Mode



Nue (top left), nuebar (top right), numu (bottom left), numubar (bottom right) flux histograms

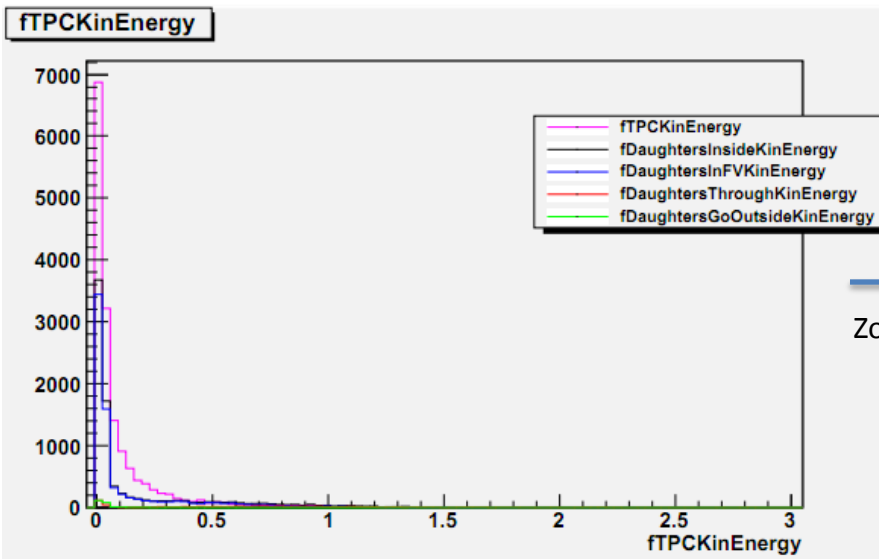
Flavor Histograms for Anti-Neutrino Mode



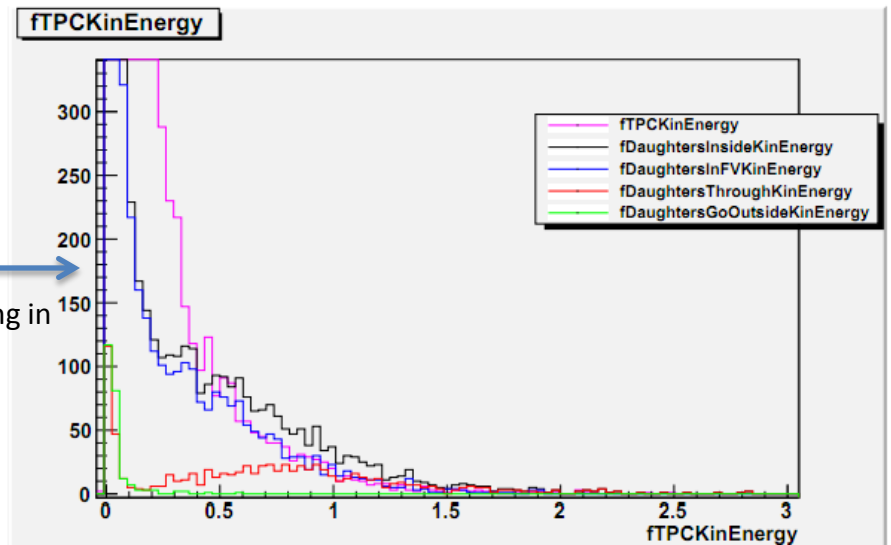
Nue (top left), nuebar (top right), numu (bottom left), numubar (bottom right) flux histograms

Energy of Daughter Particles In Fiducial Volume

- All distributions peak around 0.0 GeV, implying that many particles decay at or close to rest



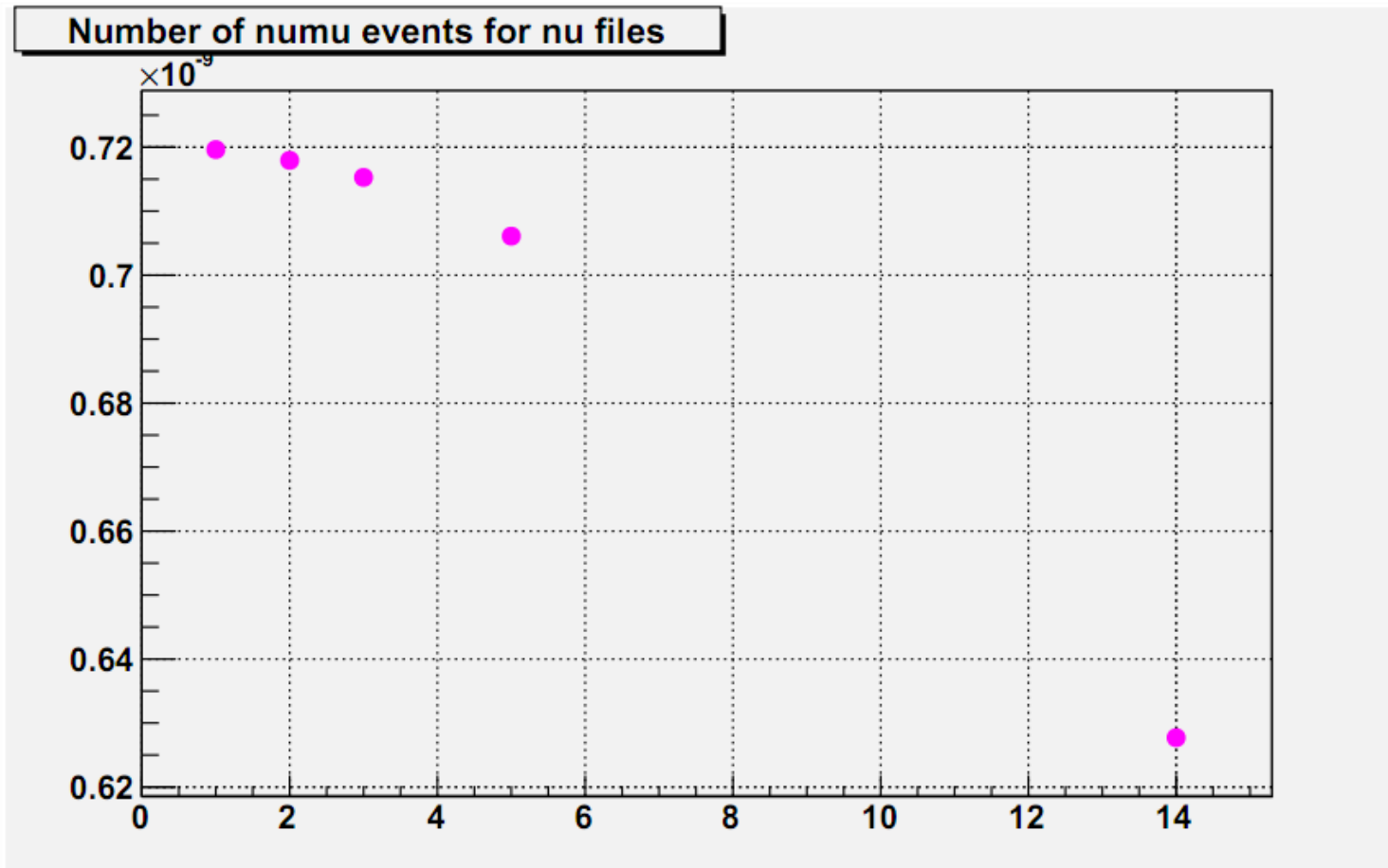
Zooming in



Obtaining Scaling Factors

- Scaling factor for neutrino mode:
- $$\frac{73.9 \text{ ton f.v.}}{4,992 \text{ events}} \times (768,000 \times 5 \times 10^{12} \text{ POT}) \times \frac{157,338 \text{ events}}{64.1 \text{ ton f.v.}} \div (6.6 \times 10^{20} \text{ POT}) = 0.211$$
- Scaling factor for anti-neutrino mode:
- $$\frac{73.9 \text{ ton f.v.}}{5,044 \text{ events}} \times (793,000 \times 5 \times 10^{12} \text{ POT}) \times \frac{87,241 \text{ events}}{64.1 \text{ ton f.v.}} \div (6.6 \times 10^{20} \text{ POT}) = 0.120$$

Number Events vs. Beam Radius (Neutrino Mode)



Number Events vs. Beam Radius (Anti-Neutrino Mode)

